Characterization of Extrasolar Planets using SOFIA

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First part of this talk:

the landscape of extrasolar planets

why focus on transiting planets

some history, Spitzer results

Posters by Angerhausen & Krabbe

+ HIPO poster by Dunham et al.

Then:

Hot Jupiters: a problem in atmospheric structure

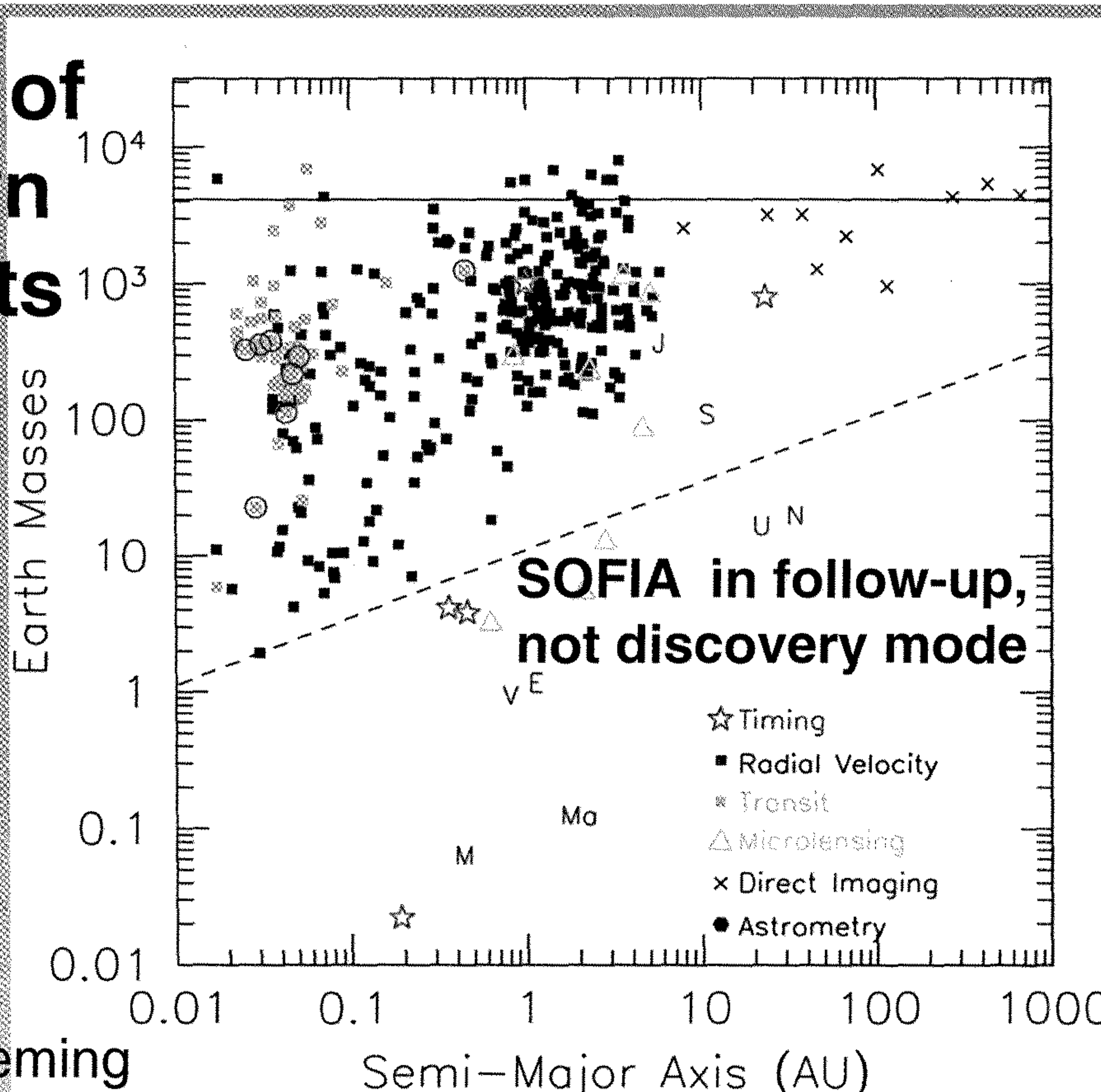
– also hot super-Earths

What observations we need to make progress

What SOFIA can currently do

and comments on optimized instruments

Summary of the known exoplanets

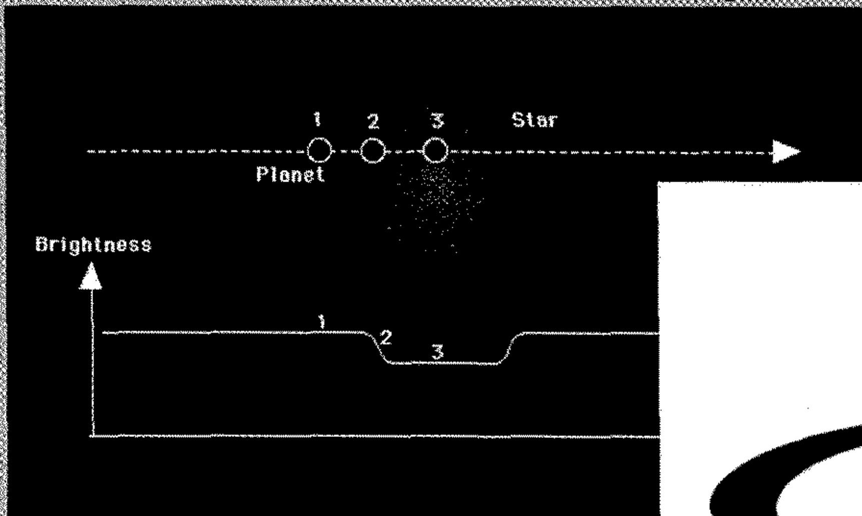


SOFIA in follow-up, not discovery mode

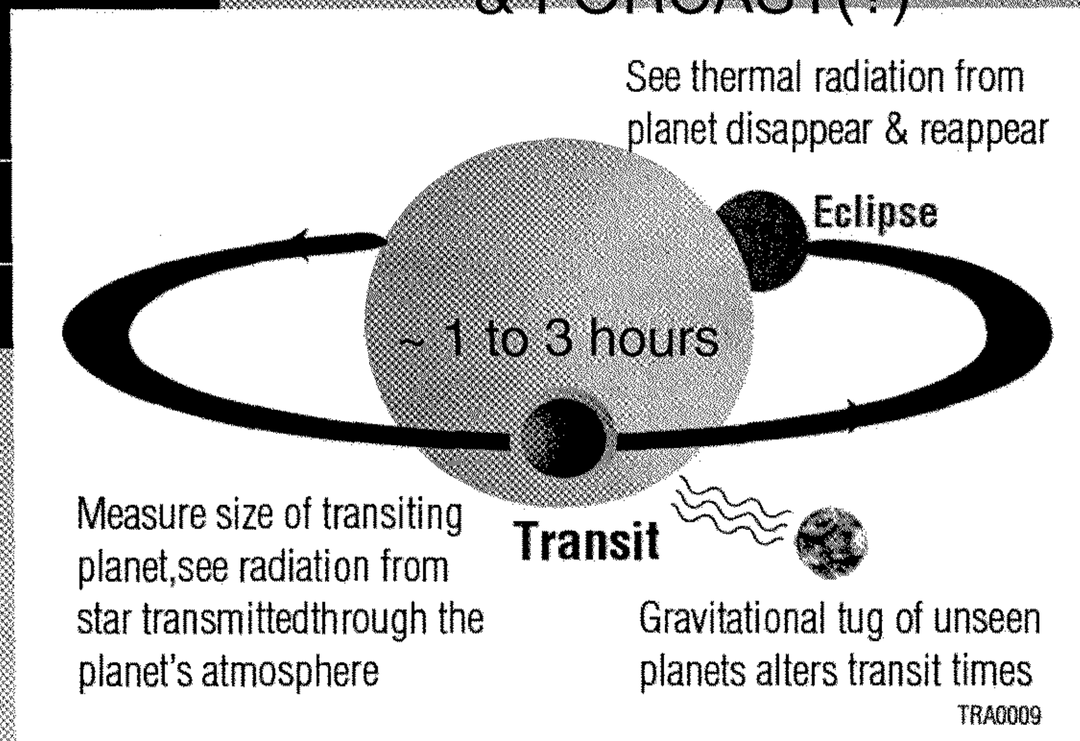
Deming & Seager review in Nature 462, 301 (2009)

Also, Seager & Deming ARAA (2010), astro-ph/1005.4037

Exploit *transits* to characterize exoplanet atmospheres...



few x 10^{-3} FLITECAM & FORCAST(?)

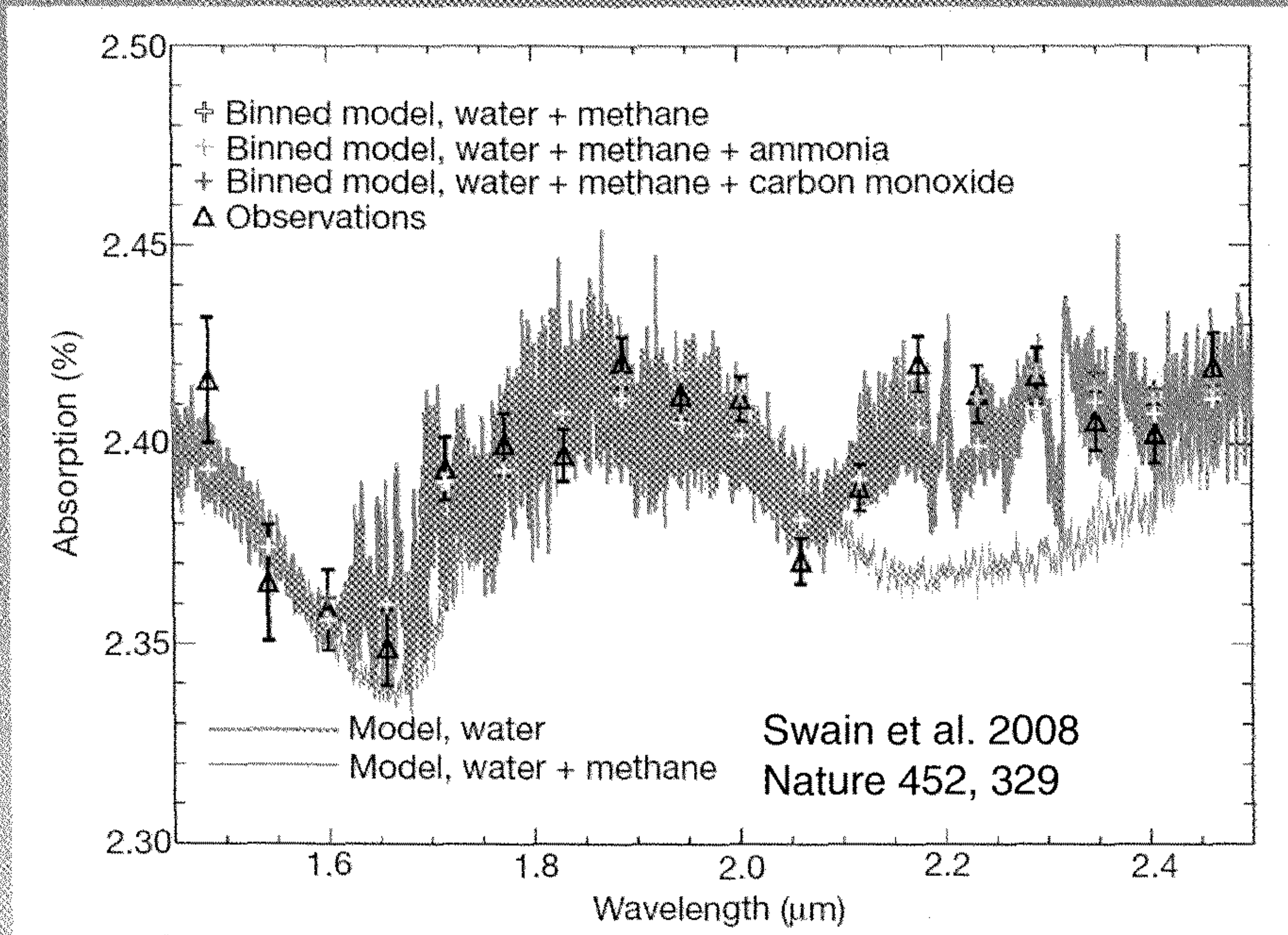


Transits require photometric stability

But tolerate poor image quality

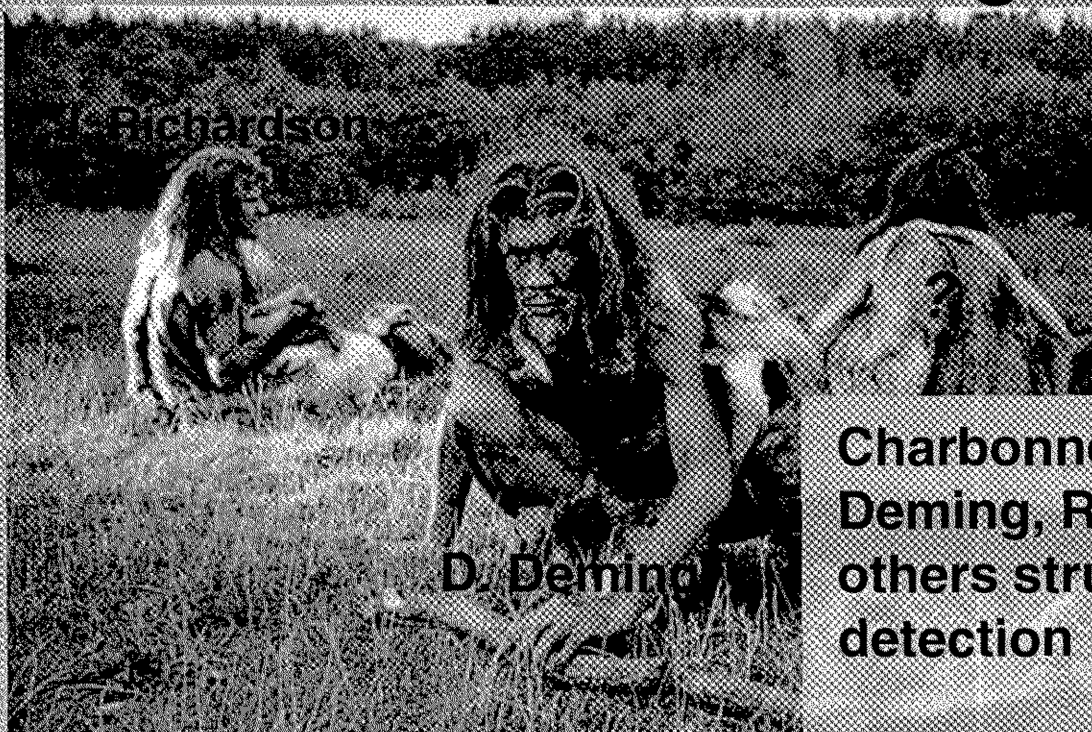
few x 10^{-4} HIPO + FLITECAM

Methane and water vapor in transmission (HD189733b)

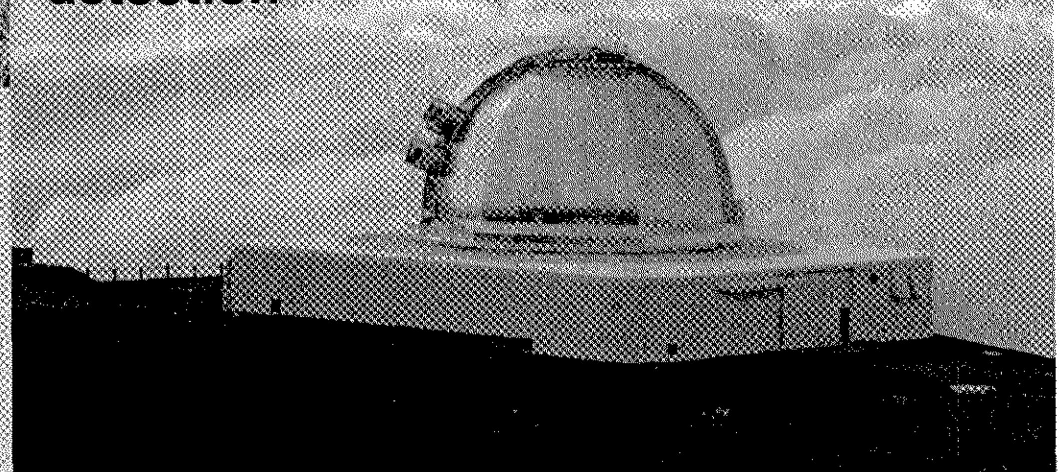


Arguably, SOFIA continuous viewing is a good tradeoff for some telluric water…

Emitted/reflected spectra of hot Jupiters in the paleolithic age (1999-2003)



Charbonneau, Brown, Collier-Cameron, Deming, Richardson, Wiedemann, and others struggled towards ground-based detection

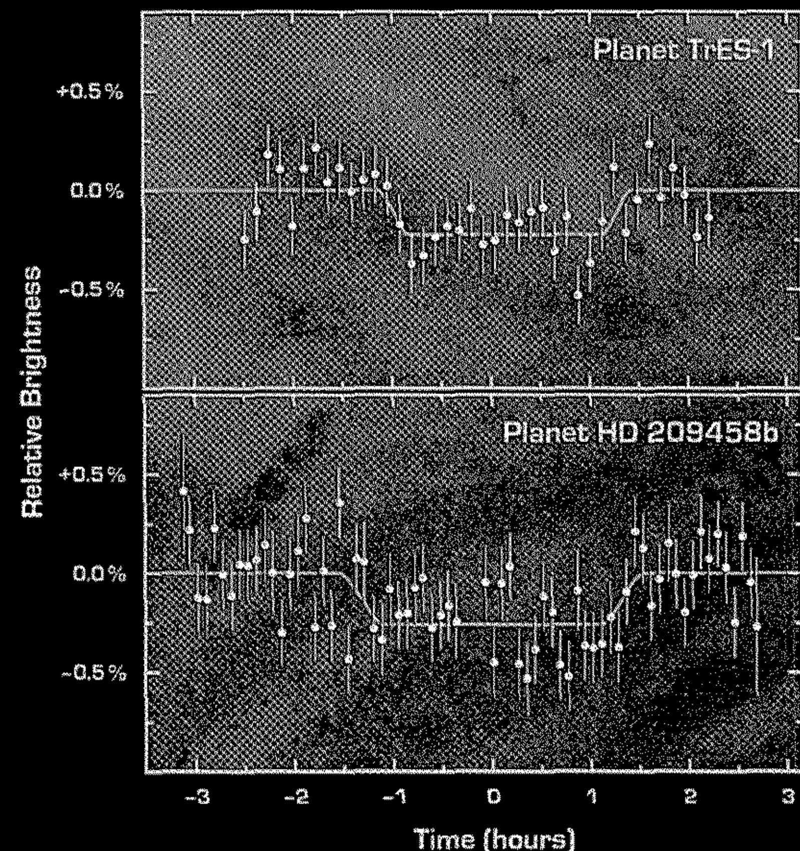


"First Light" Thermal Emission

Spitzer enables direct detection of IR light from the planets

eclipse depth ~ $(R_p/R_{star})^2(T_p/T_{star})$

yields T ~ 1100K



Planetary Eclipses Spitzer Space Telescope • IRAC • MIPS

NASA / JPL-Caltech / D. Charbonneau (Harvard-Smithsonian CfA) D. Deming (Goddard Space Flight Center) ssc2005-09a

Six Spitzer photometric bands can give a low resolution spectrum of the planet

Eclipse of HD 189733B

eclipse depth ~ $(R_p/R_{star})^2(T_p/T_{star})$

Dominant term

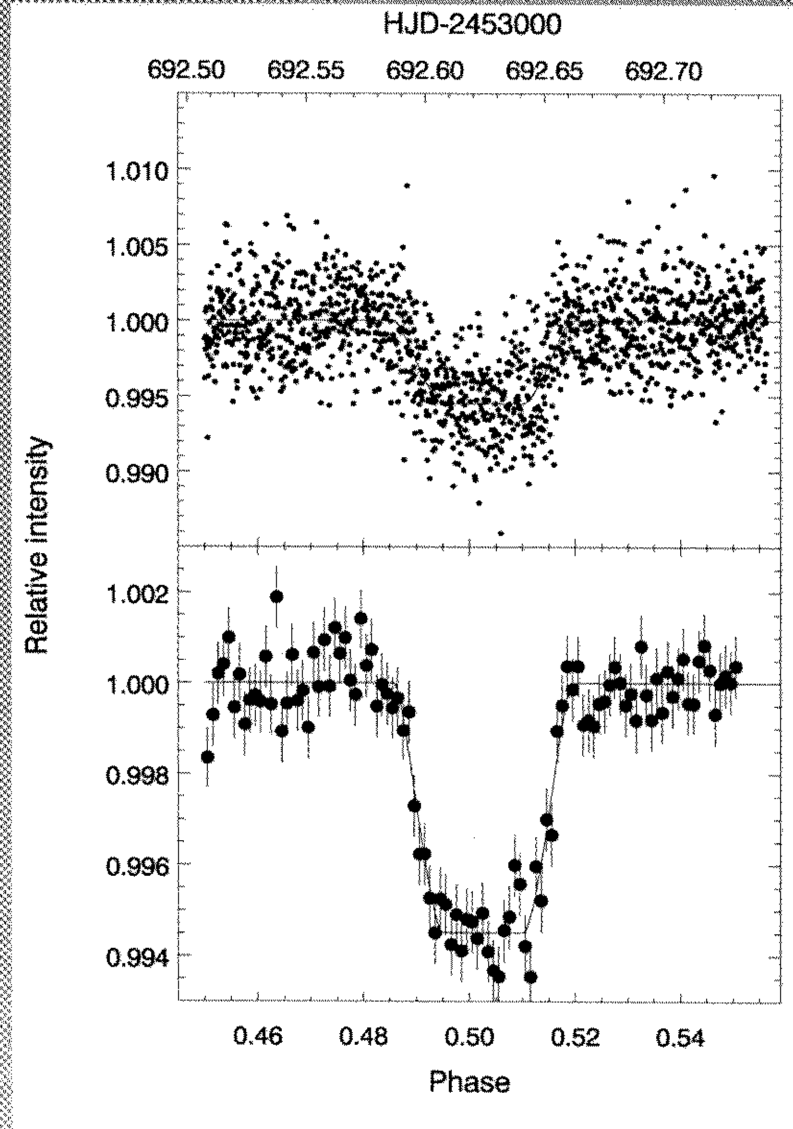
$T_p \sim T_{star}\,\Delta^{0.5}$

lower main-sequence stars allow high S/N planet detection

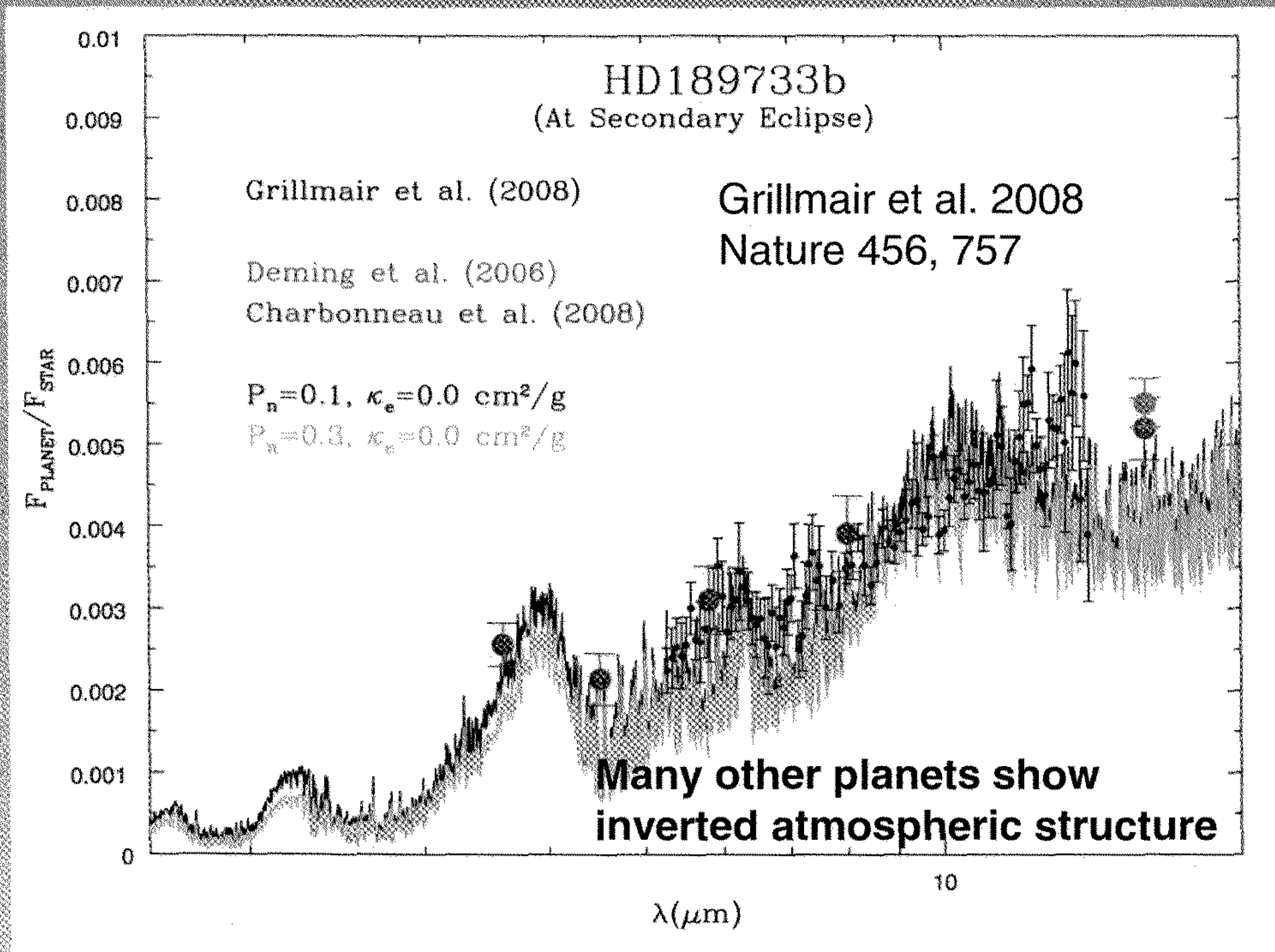
HD 189733b (K3V)

32σ detection at 16 μm

Deming et al. 2006, ApJ 644, 560



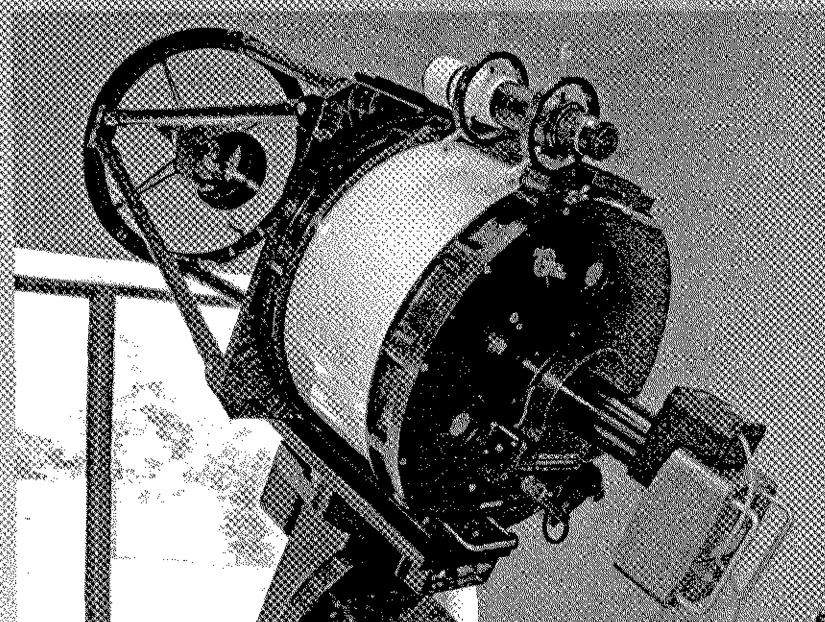
An Exoplanet Spectrum (R ~ 100)



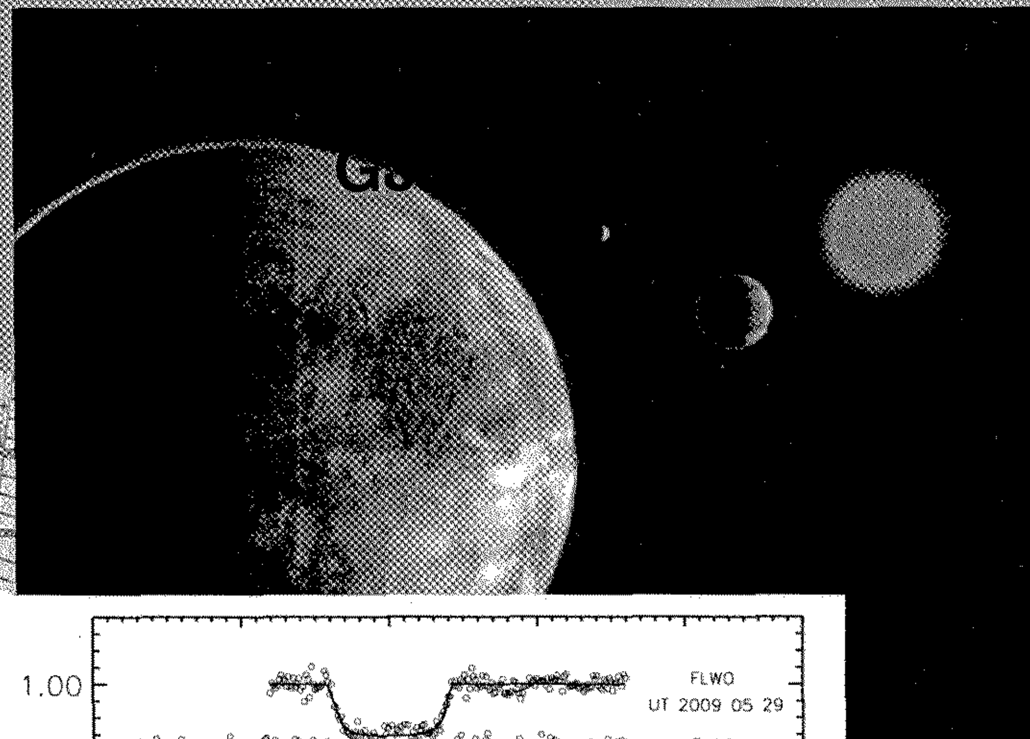
The MEarth Project

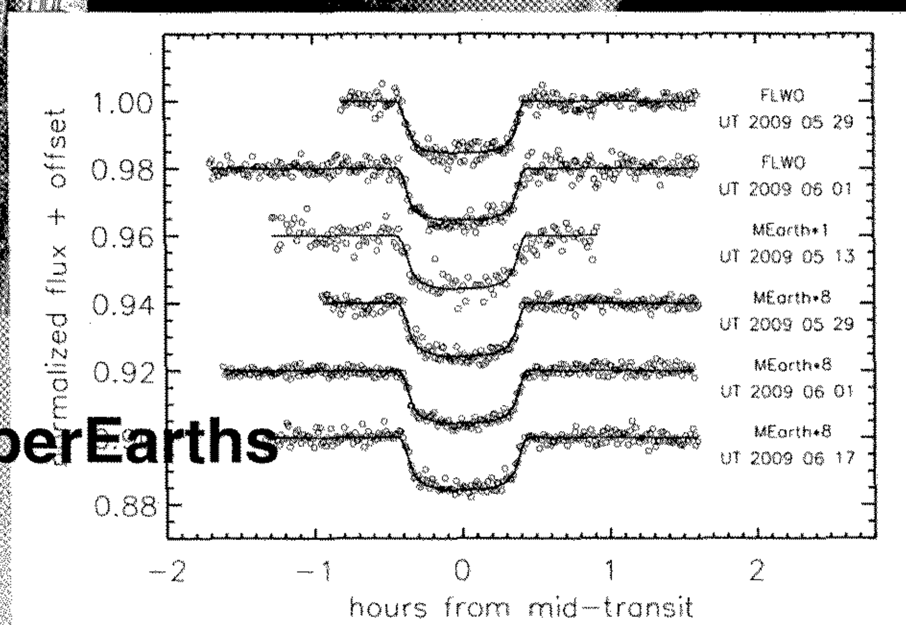
Charbonneau et al.

- Using 8 X 16-inch telescopes to survey the 2000 nearest M-dwarfs for rocky planets in their habitable zones
- Converted an existing abandoned building on Mt Hopkins, AZ
- Fully operational; southern version planned
- **These planets will be amenable to spectroscopic follow-up to search for atmospheric biomarkers**



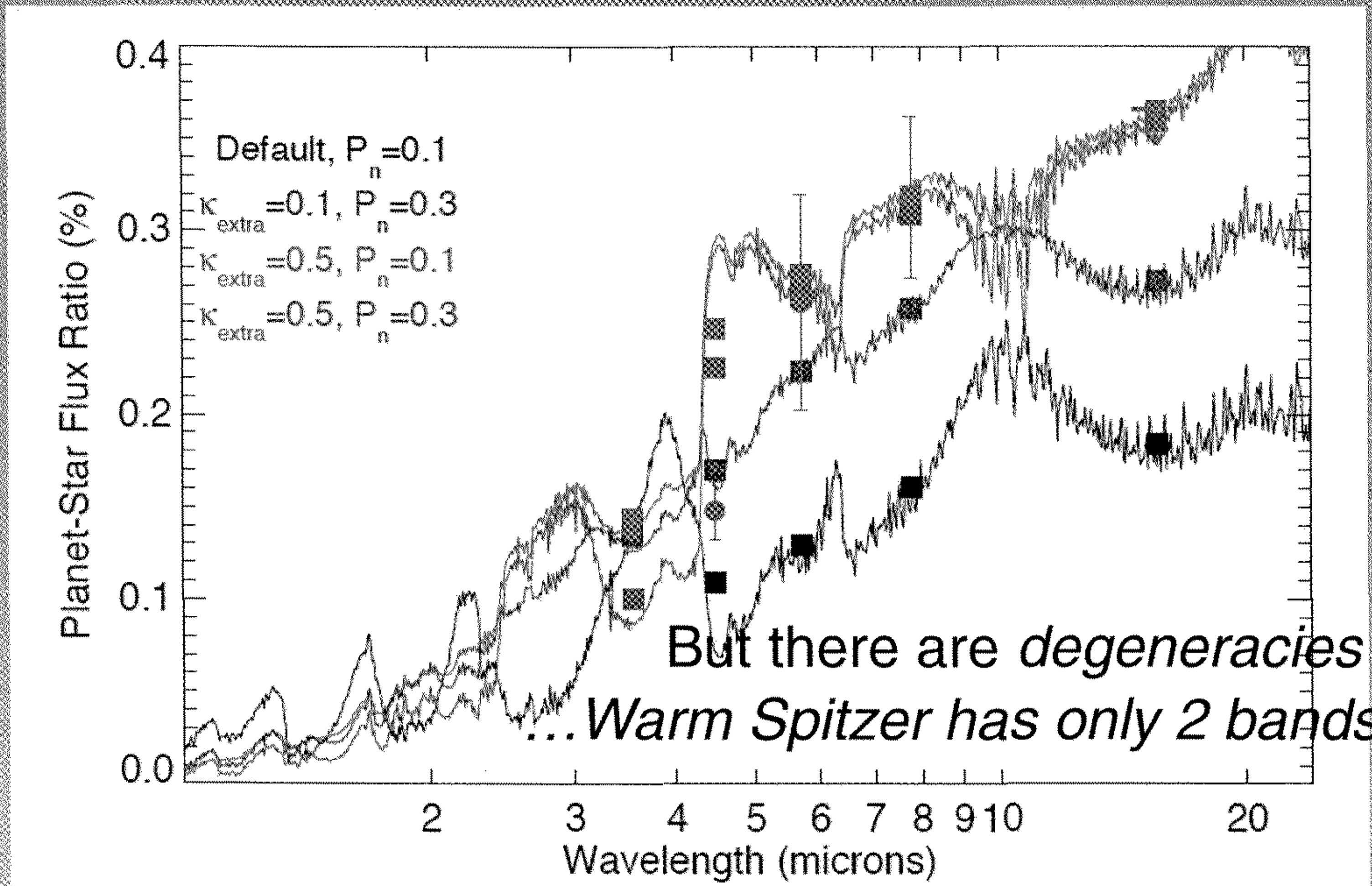
The First MEarth Super-Earth



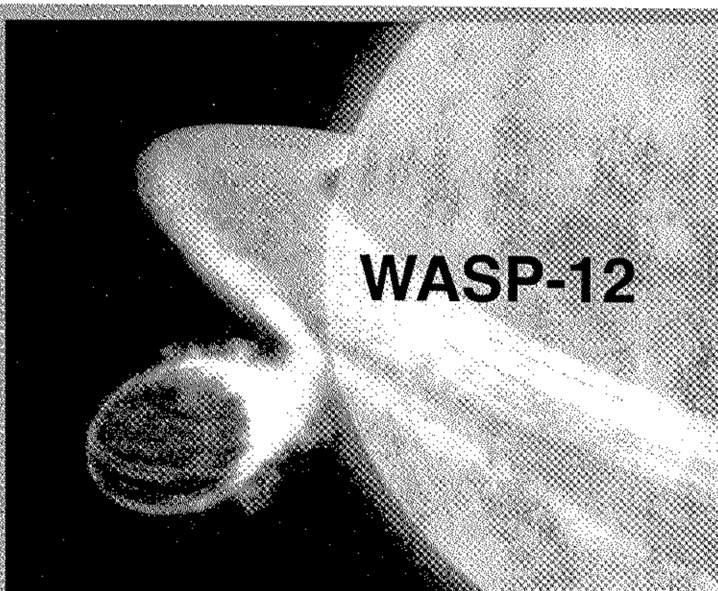


Nearby, hotter superEarths to come

TrEs-4 – apparently an inverted atmosphere

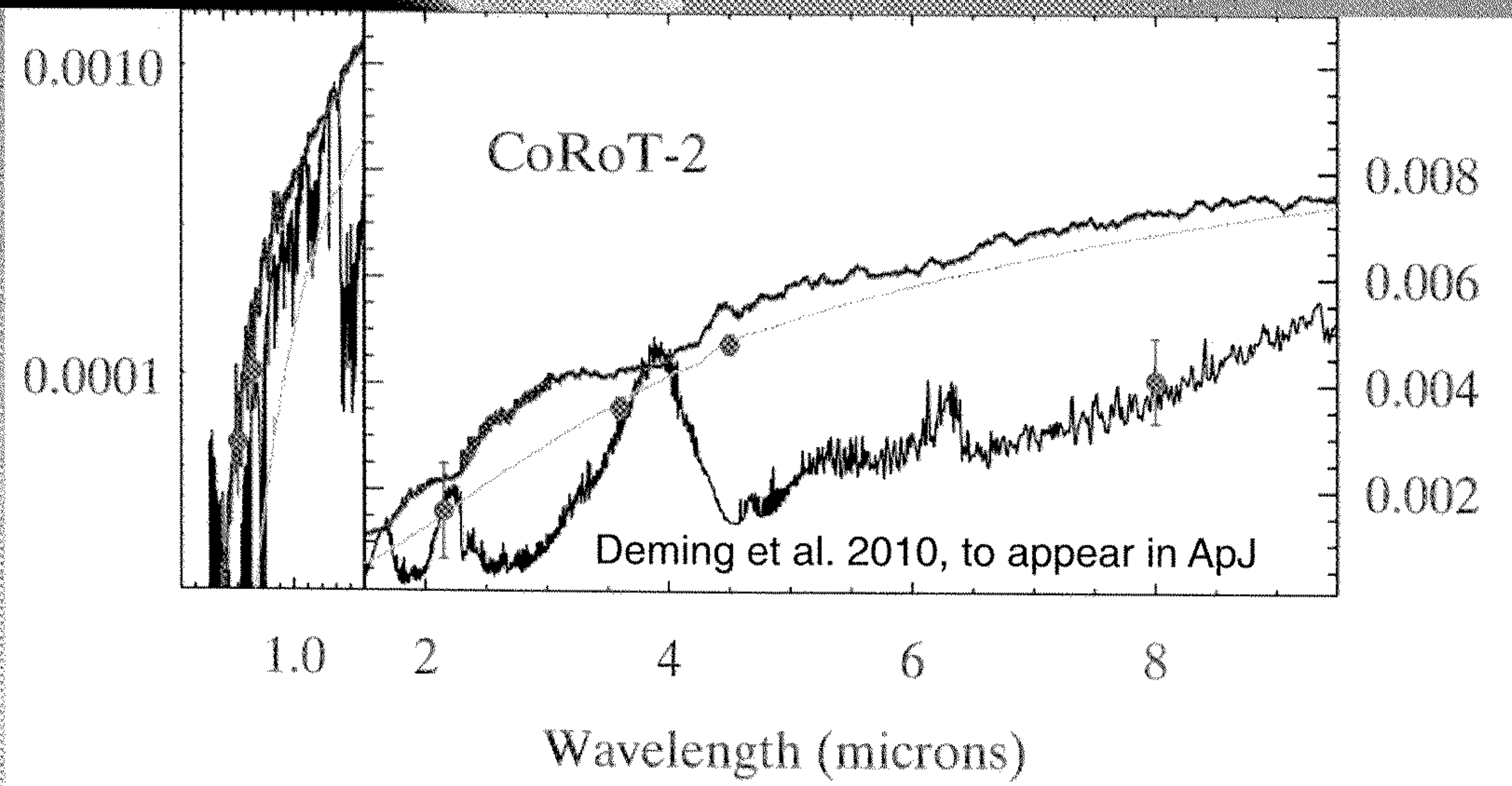


Knutson et al. ApJ 691, 866 (2009)

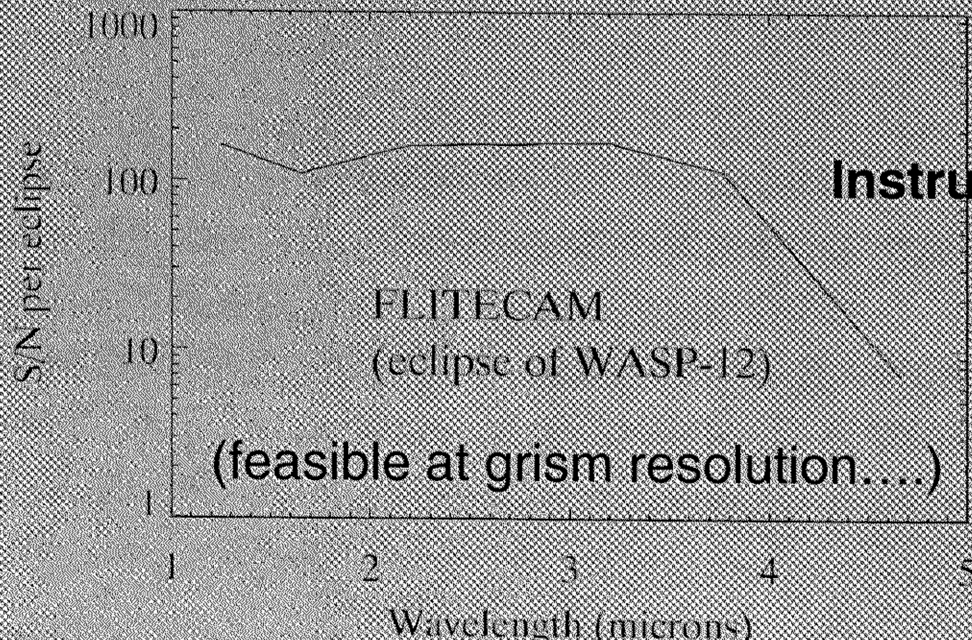


The *very hot* Jupiters atmospheres perturbed by strong irradiation?

losing mass by tidal stripping?



High S/N for WASP-12 at filter resolution



(feasible at grism resolution....)

Instrument considerations:

- **maximize the spectral range**
- **R ~ 100 is OK**
- **maximize stability**
- **consider λ-dithering**

hot super-Earths?

Conclusions and comments

- SOFIA with current instruments can make significant progress on the science of transiting exoplanets
  - Mass loss and atmospheric structure of very hot Jupiters
  - Complementary to Warm Spitzer
  - possibly can characterize hot M-dwarf super-Earths
- Instrument enhancements should concentrate on stable 1 -5 μm spectroscopy, maximizing the spectral range at relatively low spectral resolution